

REQUEST FOR ACTION (RFA) RESPONSE

GLAST LAT Project
Calorimeter Peer Review

17 – 18 March 2003

Action Item:	CAL – 010
Presentation Section:	Thermal
Submitted by:	Tom McCarthy

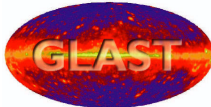
Request: Sidewall thermal analysis - Does the K-composite consider its directional nature in the composite? Was this accounted for in the analysis?

Reason / Comment: This property is different in film direction vs through-epoxy and was not noted in the analysis.

Response: 18 April 2003

Thermal conductivities of the CAL composite material were calculated in the in-plane and transverse directions. These calculations are summarized in the attached technical note, LLR-GLAST-TN-080-A.


The thermal analysis will be re-run accounting for the directional nature of the conductivities. The updated analysis is covered in RFA CAL-014.

Note Technique / Technical Note			
	<i>GLAST LAT CAL</i> <i>Mechanical Structure</i>	Ref:	GLAST-LLR-TN-080
		Issue:	A
		Date:	7 april 2003
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<i>Determination of the thermal conductivities of the CAL composite material</i>			

SLAC reference :

Change History log

A	7 april 2003	Creation	P.Prat		S. Le Quellec	O. Ferreira
Ind.	Date	Modifications	Prepared	Checked	PA Approval	Project Approval

	<i>Determination of the thermal conductivities of the CAL composite material</i>	Ref	GLAST-LLR-TN-080
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Dependence of Material Properties upon the Fiber Volume Fraction and the Resin Content

From MIL-HDBK-3F, the expressions for thermal conductivity of a lamina, in three orthogonal directions (one direct. parallel to the fibers and other two direct. perpendicular to the fibers) are:

$$k_{11} = V_f * k_{f11} + (1 - V_f) * k_m$$

and

$$k_{22} = k_m * \frac{k_{f22} * (1 + V_f) + k_m * V_m}{k_{f22} * V_m + k_m * (1 + V_f)}$$

$$k_{33} = k_{22}$$

Where,

$k_{11} = k_L$ = lamina thermal conductivity, parallel to fibers.

k_{22} & $k_{33} = k_T$ = lamina thermal conductivity, perpendicular to fibers and each other.

k_{f11} = fiber thermal conductivity, in the fiber longitudinal direction.

k_{f22} = fiber thermal conductivity, in the fiber transverse direction.

k_m = thermal conductivity of the resin matrix.

V_f = Volume fraction of fiber.

V_m = Volume fraction of matrix.

Each composite wall is constituted of fiber layers of different orientations. Let fibers in layer i be oriented at an angle θ_i with the global x_1 axis. The effective conductivities of a stack of layers of the resin and the fiber are given by :

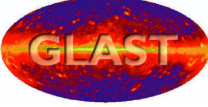
$$k_{11} = k_L \frac{\sum_{i=1}^N h_i \cos^2 \theta_i}{\sum_{i=1}^N h_i} + k_T \frac{\sum_{i=1}^N h_i \sin^2 \theta_i}{\sum_{i=1}^N h_i},$$

$$k_{12} = (k_L - k_T) \frac{\sum_{i=1}^N h_i \sin \theta_i \cos \theta_i}{\sum_{i=1}^N h_i},$$

$$k_{22} = k_L \frac{\sum_{i=1}^N h_i \sin^2 \theta_i}{\sum_{i=1}^N h_i} + k_T \frac{\sum_{i=1}^N h_i \cos^2 \theta_i}{\sum_{i=1}^N h_i},$$

$$k_{33} = k_T,$$

Where N is the number of layers and h_i is the thickness of the i th layer.

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Calculation of CAL composite conductivities

The longitudinal and transverse thermal conductivities of the TORAY T300 fiber are (source <http://www.torayca.com/techref/en/images/fcp02.html>):

$$k_{f11} = 7.3 \cdot 10^{-3} \text{ Cal / (cm. s.K)} = 3.056 \text{ W/(m.K)}$$

$$k_{f22} = 1.4 \cdot 10^{-3} \text{ Cal / (cm. s.K)} = 0.586 \text{ W/(m.K)}$$

The conductivity of epoxy is :

$$k_m = 0.2 \text{ W/(m.K)}$$

The fraction volume of fiber and epoxy are:

$$V_f = 0.55$$

$$V_m = 0.45$$

So, the longitudinal and transverse thermal conductivities of an unidirectional fiber composite laminate are:

$$k_L = 1.77 \text{ W/(m.K)}$$

$$k_T = 0.348 \text{ W/(m.K)}$$

For the walls constituted of the same number of layers of 2 perpendicular fiber orientations, the in-plane and transverse conductivities are:

$$k_{11} = k_{22} = (k_L + k_T)/2 = 1.06 \text{ W/(m.K)} \sim 1 \text{ W/(m.K)}$$

$$k_{12} = 0$$

$$k_{33} = k_T = 0.348 \text{ W/(m.K)} \sim 0.35 \text{ W/(m.K)}$$

For the walls constituted of the same number of layers of 4 fiber orientations (0° , 90° , $+45^\circ$, -45°), the in-plane and transverse conductivities are the same as above.

Conclusion

Thus, for the CAL thermal simulation , we will assumed the 2 following in-plane (k_{LC}) and transverse (k_{TC}) conductivities:

$$k_{LC} = 1 \text{ W/(m.K)}$$

$$k_{TC} = 0.35 \text{ W/(m.K)}$$